Golden Gate Inlet/Outlet Works

The Golden Gate inlet-outlet works site is about 3,200 feet directly south of the right abutment for Golden Gate Dam site in Sections 16 and 17, R4W, T17N on the Sites 7.5-minute USGS topographic quadrangle. The outlet works would include a shared intake structure, a 30-foot diameter intake-outlet tunnel with penstock extending 3,300 feet through both ridges, and a 400-foot deep vertical access shaft along the tunnel gate works. It would also include a spillway cutting across both ridges, a combination pumping plant/hydroelectric facility, and a shared approach channel that would terminate in Funks Reservoir. For the purposes of this foundation investigation, these structures have been grouped into four areas by similar topography and lithology. These are the shared intake structure, the tunnel through the ridges, the spillways, and the approach channel from the pumping plant to Funks Reservoir (Photo 18). Water from the Sacramento River will be conveyed via canal and pumped into the proposed Sites and/or Colusa Reservoirs through the pumping plant and 30-foot diameter tunnel. Releasing flows back through the tunnel and hydroelectric facility will generate power. The spillway will be required to release 10 percent of the reservoir height in 10 days. Two possible locations for the spillways exist. A smaller one is proposed north of the tunnel alignment or a larger one proposed south of the tunnel alignment.

Site Geology

The site was first mapped by USBR in 1963 as part of its *West Sacramento Canal Unit Report* (DOI-USBR 1964) and again in 1980. This mapping was used as the basis for DWR Northern District's geologic mapping of the site from September through October 1998. DWR's Division of Engineering assisted with this mapping, and both its mapping and Northern District's mapping have been incorporated into this report. The proposed facilities would be built on northerly trending, easterly dipping Cretaceous sedimentary rocks of the Boxer Formation to the west, and the Cortina Formation to the east. These formations consist of layered sandstones and mudstones, with the more resistant sandstones forming two parallel ridges, and the less resistant mudstones forming valleys in between. These ridges also comprise the various proposed Golden Gate Dam foundations to the north. Colluvial cover on the sandstone ridges averages up to 5 feet in depth. Alluvial and terrace deposits cover bedrock in the valleys to a greater depth, especially toward Funks Reservoir to the east. These Quaternary terrace deposits occur along the proposed approach channel to a depth of about 20 feet, and are composed of sand, gravel, and cobbles, mantled by a clayey soil.

Plates 6 and 7 are the geologic plan and geologic cross sections and profiles with core logs and analysis of water pressure testing at the site. Detailed logging and photodocumentation of the drill core is presented in Technical Memorandum A. Details of the water pressure testing are presented in Technical Memorandum B. Details of the piezometer construction and water levels are presented in Technical Memorandum C.

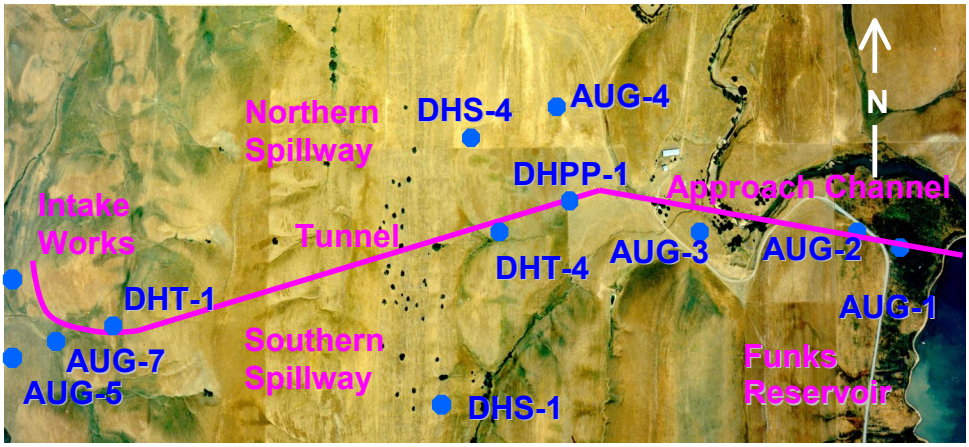


Photo 18. Aerial view of Golden Gate Inlet-Outlet Works and drill holes (see Plate 6)

Bedrock Units

The proposed Golden Gate inlet-outlet works trends nearly normal to the interlayered beds of Upper Cretaceous sandstone, siltstone, mudstone, and very minor conglomerate of the Boxer and Cortina Formations. The relative percentages of the sandstone and mudstone change frequency along the alignment. This is detailed on Plate 7, Geologic Cross Section of Golden Gate Diversion Tunnel. The shared intake structure is founded primarily on mudstone of the Boxer Formation. The diversion tunnel intersects dominantly sandstone units that comprise the two main ridges. The majority of each of the foundations for the two proposed spillways extend through these ridges, with the eastern portions terminating in a greater percentage of mudstone in the Yolo Member of the Cortina Formation. The shared approach then continues eastward across this formation, terminating in Funks Reservoir.

These bedrock units were differentiated into mappable units as follows:

- KCVs - predominantly silty sandstone (70 to 100 percent) of the Venado member of the Cortina Formation with mudstone intervals (0 to 30 percent) up to 5 feet in thickness.

- KCVsm - interbedded mudstones (30 to 70 percent) and silty sandstones (30 to 70 percent) of the Venado member of the Cortina Formation.

- KBm - predominantly mudstone (70 to 100 percent) of the Boxer Formation with silty sandstone intervals (0 to 30 percent) up to 5 feet thick.

Sandstone is the most resistant rock type at the site and comprises about 55 percent of the total areal extent of the spillways and tunnel alignment. Where fresh, it is light to medium olive gray in color, but where weathered, it is yellowish brown. The sand is very fine to medium grained, angular to subangular, and poorly sorted. The matrix is mostly calacareous clay. Bedding is thin to massive and outcrops in layers ranging from less than a foot to tens of feet in thickness. It contains thin interbeds of siltstone and mudstone that range from laminar up to 5-feet thick. It is mostly weathered near the surface and slightly weathered to a depth of at least 20 feet. It is moderately to well indurated, moderately to slightly fractured, moderately hard to very hard, and strong. Internal structure is well developed where laminar and vague where massive. Fractures are commonly healed with calcite and minor pyrite.

The sandstone also grades transitionally into siltstones. These are olive gray when fresh to olive green where weathered, and contain sandstone and mudstone interbeds. The siltstone is moderately to well indurated, moderately hard to hard and strong, and moderately to slightly fractured.

Mudstone is the least resistant rock type in the area and comprises about 45 percent of the total areal extent of the spillways and tunnel alignment. Where fresh, it is dark gray to black in color; it's tan where weathered. Bedding is laminar with thin sandstone and siltstone interbeds. It is brittle, and in outcrop it slakes readily when exposed to air and moisture. It is moderately indurated to friable, moderately hard to weak, and closely fractured.

Unconsolidated Deposits

Unconsolidated deposits overlying the bedrock for the proposed structures consist of Quaternary stream channel deposits of sand and gravel, several stream terraces, colluvium, and landslides. The approach channel to Funks Reservoir also crosses alluvium in Funks Creek. The alluvium consists of sand and gravel with lesser amounts of clay, silt, and cobbles, and with depths averaging up to 5 feet. Minor alluvium also occurs as deposits from minor drainages along the slope breaks off each of the ridges and as discontinuous deposits in the north-draining gully between these ridges. A terrace deposit (Qt2) up to 36-feet thick overlies most of the foundation for the shared approach channel. It has moderate soil development. The upper part of this terrace is clayey silt with a clay content that increases with depth. The upper 2 to 3 feet is very dark grayish brown that becomes lighter with depth to a dark grayish brown. A few gravel lenses are exposed along the sides of the incised stream channel of Funks Creek and also encountered in several of the auger holes. In places there is a clay bed at the base of the observable deposit. This terrace may be correlative with the Lower Modesto Formation as mapped by Helley and Harwood (Calif., Sacramento Valley 1982).

Colluvium occurs at the base of the steeper slopes and consists of clayey silt and sand with angular rock fragments. The colluvium ranges up to 5 feet in thickness overlying bedrock and terrace deposits at the base of the hillsides. Numerous landslides exist that have yet to be mapped. They are mostly shallow seated earth flows that are relatively small in scale.

Structure

The primary structural feature at the Golden Gate inlet-outlet works is the northerly striking, east-dipping homoclinal bedding of the Great Valley sequence. Local attitudes vary in strike from N10°W to N10°E, and bedding dips eastward, ranging from 45 to 55 degrees. These bedding attitudes are fairly uniform within the project area.

Faults and Folds

USGS mapped the Salt Lake thrust fault and three associated right lateral tear faults at and in the vicinity of the Golden Gate outlet works (Calif., Glenn and Colusa Counties 1961). The regional trend for these tear faults is to the northeast with a near vertical dip. Associated with these faults are narrow zones of gouge, slickensides, and sheared mudstone.

The northerly trending Salt Lake fault parallels the western side of the main sandstone ridges where the facilities would be located. It is about a half mile to the west of the inlet works (WLA 1997).

William Lettis and Associates have trenched these faults as part of its DWR-funded phase II fault and seismic investigation.

Tear fault GG-2 starts just east of the Salt Lake fault about 2 miles north of the town of Sites. It then extends to the northeast about a half mile where it trends through the intake channel for the proposed intake works, continuing northeast about another 3 miles.

Tear fault GG-3 starts close to the town of Sites, then extends to the northeast about 2 miles where it trends through the proposed upstream dam spillway and the approach channel to the pumping plant (Photo 19). It parallels and is between the NE tear fault S-2 that trends through Sites Dam site to the south and the NE GG-2 fault that trends through Golden Gate Dam site to the north. There may be another smaller northeastern splay off this fault that would intersect the outlet works farther east in the Funks Creek channel.

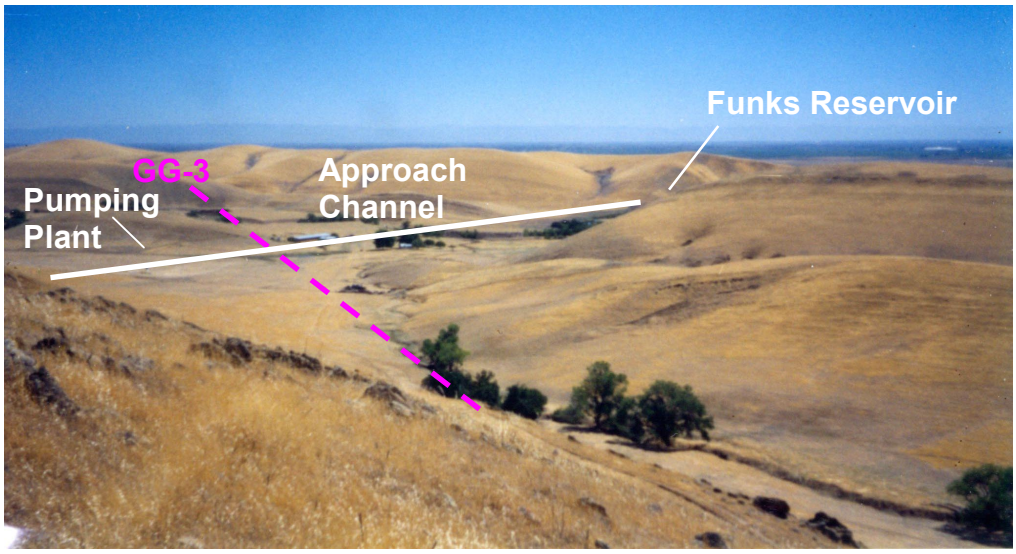


Photo 19. Northeast view of GG-3 fault relative to the approach channel (View from top of ridge at proposed southern spillway)

Joints

At least two distinct joint sets have been mapped at the central ridges for the Golden Gate outlet works. The dominant joint set trends roughly east west with near vertical dips. A secondary set trends N60°E with a generally NW dip averaging 70 to 80 degrees. There may be some jointing associated with the GG-3 fault, as suggested by jointing attitudes in outcrops that roughly parallel the western side of the fault in the Funks Creek channel.

Foundation and Tunneling Conditions and Exploration

The bedrock that the inlet-outlet works, tunnel, pumping plant, spillways, and approach channels will be excavated in should provide a good foundation for the works as proposed. The sedimentary rocks comprising the ridges are not anticipated to create difficult tunneling conditions. These rocks should also be easily excavated at either of the possible spillway locations. Only moderate clearing and stripping will be required. Also, numerous small shallow earth flows would be removed. At least two faults intersect some of the proposed structures but are not active. One of these, GG-3, intersects the southern spillway and pumping plant foundation; the other, GG-2, intersects the intake channel foundation. Neither should present a problem for construction. Table 10 summarizes the foundation conditions, and Figure 6 summarizes the surficial geology for each of the proposed components.

The site was mapped on a regional scale initially by USGS in 1961, by USBR in 1963 and 1980, and then modified by DWR's Northern District with assistance from DWR's Division of Engineering. Mapping the central sandstone ridges generally showed good exposure of outcrops. Mapping of the western-shared intake foundation and eastern approach channel was more difficult due to limited exposures.

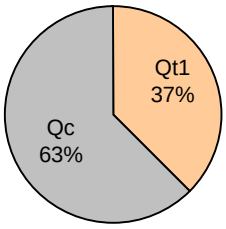
TABLE 10 –Sites Reservoir Project, Golden Gate Inlet - Outlet Works Foundation Conditions

FEATURE	AREAL GEOLOGY	CLEARING ESTIMATES	STRIPPING ESTIMATES	WATER LEVELS	GROUTING ESTIMATES	STRUCTURAL REMARKS
Shared Intake Works Width Max. = 830 feet Length Max. = 2,200 feet Elev. Max. = 390 feet Elev. Min. = 290 feet Drill holes = DHT-1, AUG-5, AUG-6, AUG-7 Seismic = SL-12, SL-13	Surficial Qt_1 = 325,000 $feet^2$ (37%), Qc = 543,400 $feet^2$ (63%), Total Area = 868,400 $feet^2$ Bedrock KBsm = 814,200 $feet^2$(94%), KBm = 54,200 $feet^2$ (6%) ,Total Area = 868,400 $feet^2$ therefore: Ss = from 224,300 $feet^2$ (28%), to 586,200 $feet^2$ (68%), Ms = from 624,100 $feet^2$ (72%) to 282,200 $feet^2$ (32%)	LIGHT: Open pastureland with scattered grasses and rare brush.	The upper 20 feet of soil, colluvium, and intensely weathered rock can be stripped with common methods. An additional 4 feet of moderately weathered rock may need to be excavated.	In the Summer and Fall of 1999 the depth to water below ground surface varied from 7.3 to 8.5 feet below ground surface at AUG-6 and 29 to 30 feet at DHT-1.	DWR Drill Hole DHT-1: High grout takes at 9 to 20 feet in intensely weathered and fx Ms/Ss, and at 103 to 114 feet in fx Ms/Ss. Low grout takes at 82 to 93 feet in fx Ms/Ss.	Fault (GG-2) strikes N65°E through the northern end.
Gate Intake and Penstock Width = 750 feet Length =800 feet Elev. Max. = 730 feet Elev. Min. = 540 feet Elev. Peak = 800 feet. Not drilled. No seismic.	Surficial Qc = 439,300 $feet^2$ (100%), Total Area = 439,300 $feet^2$ Bedrock KBm = 184,900 $feet^2$ (42%), KCVs = 254,400 $feet^2$ (58%),Total Area = 439,300 $feet^2$ Therefore: Ss = from 178,100 $feet^2$ (41%) to 309,800 $feet^2$ (71%), Ms = from 261,200 $feet^2$ (59%) to 129,400 $feet^2$ (29%)	LIGHT: Open pastureland with scattered grasses.	Not Drilled	Not drilled	Not drilled.	Bedding strikes north-south; dip averages 50 degrees east
Shared Diversion Tunnel Width = 30 feet Length = 4,000 feet Elev. Max. = 350 feet Elev. Min. = 270 feet Drill holes = DHT-1, DHT-4	Surficial Qt_1 = 900 $feet^2$ (0.5%), Qc = 185,600 $feet^2$ (99.5%), Total Area =186,500 $feet^2$ Bedrock KBsm = 30,600 $feet^2$ (16%), KBm = 37,500 $feet^2$ (20%), KCVs = 64,100 $feet^2$ (34%), KCVsm = 36,000 $feet^2$ (19%), KVm = 18,300 $feet^2$ (10%), Total Area = 186,500 $feet^2$ therefore: Ss = from 64,900 $feet^2$ (35%), to 127,500 $feet^2$ (68%), Ms = from 121,700 $feet^2$ (65%) to 59,100 $feet^2$ (32%)	Not Applicable (Subsurface)	The upper 20 feet of soil, colluvium, and intensely weathered rock can be stripped with common methods. An additional 5 feet of moderately weathered rock may need to be excavated.	In the Summer and Fall of 1999 the depth to water below ground surface varied from 29 to 30 feet at DHT-1 and 9 to 11 feet at DHT-4.	DWR Drill Hole DHT-1: High grout takes at 9 to 20 feet in intensely weathered and fx Ms/Ss, and at 103 to 114 feet in fx Ms/Ss. Low grout takes at 82 to 93 feet in fx Ms/Ss. DWR Drill Hole DHT-4: High grout takes at 17 to 70 feet in fx/sheared Ms/Ss.	Bedding strikes north-south; dip averages 50 degrees east
Pumping Plant Width = 1,100 feet Length = 1,800 feet Elev. Max. = 350 feet Elev. Min. = 240 feet Drill holes = DHPP-1, Seismic = SL-9	Surficial Qt_1 = 871,100 $feet^2$ (57%), Qc = 656,600 $feet^2$ (43%), Total Area = 1,527,700 $feet^2$ Bedrock KCVs = 93,100 $feet^2$ (6%), KCVsm = 1,240,600 $feet^2$ (81%), KCVm = 194,000 $feet^2$ (13%), Total Area = 1,527,700 $feet^2$ therefore: Ss = from 437,300 $feet^2$ (29%) to 1,019, 700 $feet^2$ (67%), Ms = from 1,090,400 $feet^2$ (71%) to 508,000 $feet^2$ (33%)	LIGHT: Open pastureland with scattered grasses and rare brush.	The upper 10 to 27 feet of soil, colluvium, and intensely weathered rock can be stripped with common methods. An additional 10 feet of moderately weathered rock may need to be excavated.	In the Summer and Fall of 1999 the depth to water below ground surface varied from12 to 15 feet at DHPP-1.	DWR Drill Hole DHPP-1: High grout takes at 6 to 38 feet in weathered and fx/sheared Ss/Ms, at 79 to 111 feet in fx Ss/Ms, and at 142 to 164 feet in fx Ss/Ms.	Fault (GG-3) strikes N40°E through the eastern end.
Northern Spillway Alternative #1 Width = 950 feet Length = 2,900 feet Elev. Max. = 610 feet Elev. Min. = 245 feet Drill hole = DHS-4, AUG-4 Seismic = SL-8	Surficial Qt_1 = 117,900 $feet^2$ (8%), Qc = 1,311,600 $feet^2$ (92%), Total Area = 1,429,500 $feet^2$ Bedrock KCVs = 427,900 $feet^2$ (30%), KCVsm = 653,200 $feet^2$ (46%), KCVm = 348,400 $feet^2$ (24%), Total Area = 1,429,500 $feet^2$ therefore: Ss = from 495,500 $feet^2$ (35%) to 989,700 $feet^2$ (69%), Ms = from 934,000 $feet^2$ (65%) to 439,800 $feet^2$ (31%)	LIGHT: Open pastureland with scattered grasses and rare brush.	The upper 7 feet of soil, colluvium, and intensely weathered rock can be stripped with common methods. An additional 7 feet of moderately weathered rock may need to be excavated.	In the Summer and Fall of 1999 the depth to water varied from being dry to 27 feet below ground surface at DHS-4	DWR Drill Hole DHS-4: High grout takes at 6 to 38 feet in weathered and fx Ms/Ss.	Bedding strikes north-south; dip averages 50 degrees east
Southern Spillway #2 Width (Avg.) = 1,000 feet Width (Max.) = 2,900feet ~350 feet wide Length = 5,000 feet Elev. Max. = 730 feet Elev. Min. = 240 feet Drill holes = DHS-1, FT6-AUG-1, FT6-AUG-2, FT6-AUG-3, FT6-AUG-4 No Seismic	Surficial Qt_1 = 152,300 $feet^2$ (4%), Qc = 4,194,300 $feet^2$ (96%), Total Area = 4,346,600 $feet^2$ Bedrock KBm = 152,500 $feet^2$ (4%), KCVs = 1,566,900 $feet^2$ (36%), KCVsm = 2,313,500 $feet^2$ (53%), KCVm = 313,700 $feet^2$ (7%),Total Area = 4,346,600 $feet^2$ therefore: Ss = from 1,790,900 $feet^2$ (41%) to 3,326,200 $feet^2$ (77%), Ms = from 2,555,700 $feet^2$ (59%) to 1,020,400 $feet^2$ (23%)	LIGHT: Open pastureland with scattered grasses and rare brush.	The upper 15 feet of soil, colluvium, and intensely weathered rock can be stripped with common methods. Additional 17 feet of moderately weathered rock may need to be excavated.	In the Summer and Fall of 1999 the depth to water below ground surface varied from 16 to 17 feet at FT6-AUG-1 and DHS-1 has been artesian continuously since being drilled	DWR Drill Hole DHS-1: High grout takes at 16 to 38 feet in fx/sheared Ss.	Fault (GG-3) strikes N40°E along the eastern dip-slope of ridge. Possible fault (lineament) strikes at N55°E near the eastern end of spillway.
Shared Outlet Width = 500 feet Length = 4,300 feet Elev. Max. = 240 feet Elev. Min. = 200 feet Drill holes = AUG-1, AUG- 2, AUG-3 Seismic = SL-10, SL-11	Surficial Qt_1 = 498,900 $feet^2$ (46%), Qt_2 = 139,900 $feet^2$ (13%), Qal = 34,600 $feet^2$ (3%), Qc = 410,900 $feet^2$ (38%), Total Area = 1,084,300 $feet^2$ Bedrock KCVs = 154,500 $feet^2$ (12%), KCVsm = 1,126,100 $feet^2$ (88%), Total Area = 1,280,600 $feet^2$ Therefore: Ss = from 446,000 $feet^2$ (35%) to 942,700 $feet^2$ (74%), Ms = from 834,600 $feet^2$ (65%) to 337,800 $feet^2$ (26%)	LIGHT: Open pastureland with scattered grasses and rare brush.	Auguring indicates up to 36 feet of soil, colluvium, and intensely weathered rock can be stripped with common methods. The additional depth to fresh bedrock is unknown.	In the Summer and Fall of 1999 the depth to water below ground surface varied from24 to 25 feet at AUG-3	Not drilled.	Possible Fault (lineament) strikes at N60°E near the eastern end.

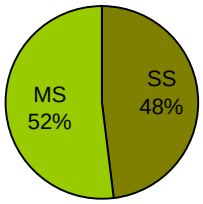
Ss = Sandstone Ms = Mudstone Cgl = Conglomerate Qal = Quaternary Alluvium Qc = Quaternary Colluvium Qt_1 = Quaternary Terrace (lower) Qt_2 = Quaternary Terrace (upper) Fx = Fracturing

FIGURE 6: Sites Reservoir Project, Golden Gate Inlet-Outlet Works Foundations, Surficial and Bedrock Lithology By Percentage

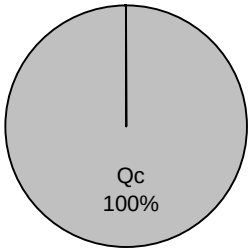
Areal Surficial Lithology of the Shared Intake Foundation



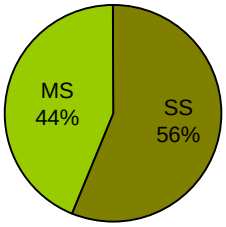
Areal Bedrock Lithology of the Shared Intake--Average Proportion of Sandstone and Mudstone



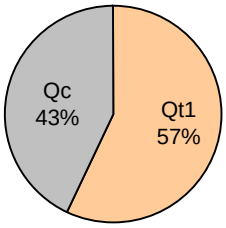
Areal Surficial Lithology of the Gate Works



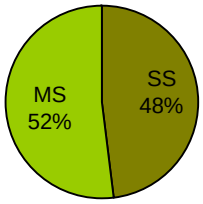
Areal Bedrock Lithology of the Gate Works - Sandstone Minimum/ Mudstone Maximum



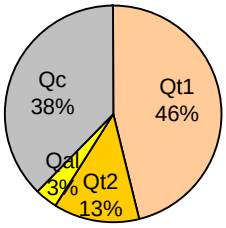
Areal Surficial Lithology of the Power Plant Foundation



Areal Bedrock Lithology of the Power Plant Foundation -- Sandstone Minimum /Mudstone Maximum



Areal Surficial Lithology of the Shared Outlets Approach Channel



Areal Bedrock Lithology of the Shared Outlets Approach Channel--Sandstone Minimum /Mudstone Maximum

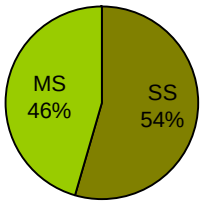
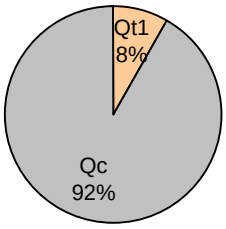
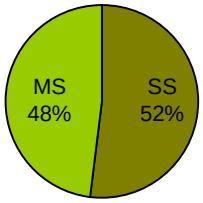


FIGURE 6: (continued)

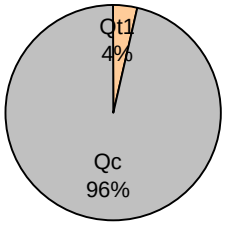
Areal Surficial Lithology of the Northernmost Spillway



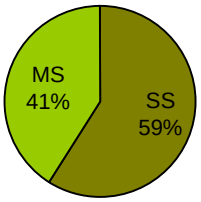
Areal Bedrock Lithology of the Northernmost Spillway--Sandstone Minimum/Mudstone Maximum



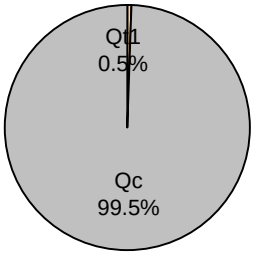
Areal Surficial Lithology of the Southernmost Spillway



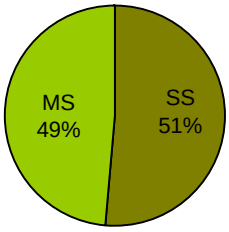
Areal Bedrock Lithology of the Southernmost Spillway--Sandstone Minimum/Mudstone Maximum



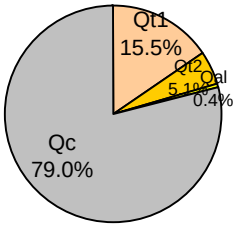
Areal Surficial Lithology of the Tunnel



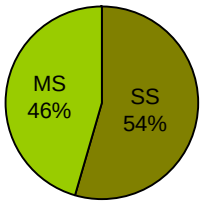
Areal Bedrock Lithology of the Tunnel--Sandstone Minimum/Mudstone Maximum



Total Areal Surficial Lithology of the Outlet Works



Areal Bedrock Lithology of the Outlet Works Footprint-Sandstone Minimum/Mudstone Maximum



In spring 1999 DWR's Northern District contracted with Layne-Christensen Drilling to provide drilling and testing services as part of this investigation. Five vertical diamond core and seven auger holes were drilled in summer 1999 to evaluate foundation and tunneling conditions (Table 11). One core hole was drilled at the proposed pumping plant, one at each portal of the inlet-outlet tunnel, and one each at the possible spillways. Each of these was water pressure tested to estimate grouting requirements (Technical Memorandum B). The auger holes were augured to bedrock along the shared intake and approach channels.

Table 11. DWR drilling footage of the Golden Gate Inlet-Outlet Works

Drill Site	Drill Hole	Date Started	Date Completed	Drilled Footage
Golden Gate Outlet Works	DHPP-1	Jun 22, 1999	Jun 24, 1999	199.6
	DHPP-1B	Jun 26, 1999	Jun 26, 1999	20.3
	DHT-1	Jun 27, 1999	Jun 30, 1999	224.5
	DHT-4	Jul 06, 1999	Jul 08, 1999	199.5
	DHS-4	Jul 10, 1999	Jul 12, 1999	199.5
	DHS-1	Jul 13, 1999	Jul 19, 1999	199.0
	Total HQ Diamond Drill Footage			1042.4
	AUG-3	Jun 26, 1999	Jun 26, 1999	36.3
	AUG-5	Jun 30, 1999	Jun 30, 1999	13.4
	AUG-6	Jun 30, 1999	Jun 30, 1999	19.0
	AUG-7	Jun 30, 1999	Jun 30, 1999	5.9
	AUG-2	Jul 01, 1999	Jul 01, 1999	13.5
	AUG-4	Jul 13, 1999	Jul 13, 1999	13.9
	AUG-1	Jul 22, 1999	Jul 22, 1999	11.0
	Total Auger Footage			113.0
	Total Footage			1155.4

LA = Left abutment drill hole
LC = Left channel drill hole
RC = Right channel drill hole
RA = Right abutment drill hole
DHPP = Drill hole power plant
DHS = Drill hole spillway
DHT = Drill hole tunnel
SSD = Sites saddle dams
AUG = Auger hole

Shared Intake Structure

The shared intake structure consists of a 2,200-feet long by 830-feet wide concrete apron that will channel water to the western tunnel portal on the east side of the Sites Reservoir. The northern end of this intake follows a local drainage north to Funks Creek. The intake invert would range in elevation from 290 feet on the western end to 390 feet on the eastern end with a grade of about 4.5 percent. Excavation is estimated to be about 80 percent mudstone of the Boxer Formation with 20 percent sandstone and siltstone interbeds. It will be below the perched groundwater table, so dewatering will be required. Some small surficial slumps exist

on the upslope end of the foundation. Vegetation is very light, consisting primarily of open pasture land. Holes AUG-5 through AUG-7 were augered to evaluate the depth of soil and foundation suitability along the proposed intake canal (Photo 20). AUG-5 was augered to a depth of 13.4 feet, AUG-6 to a depth of 19.0 feet, and AUG-7 to a depth of 5.9 feet to refusal. They all encountered clayey colluvial soil.

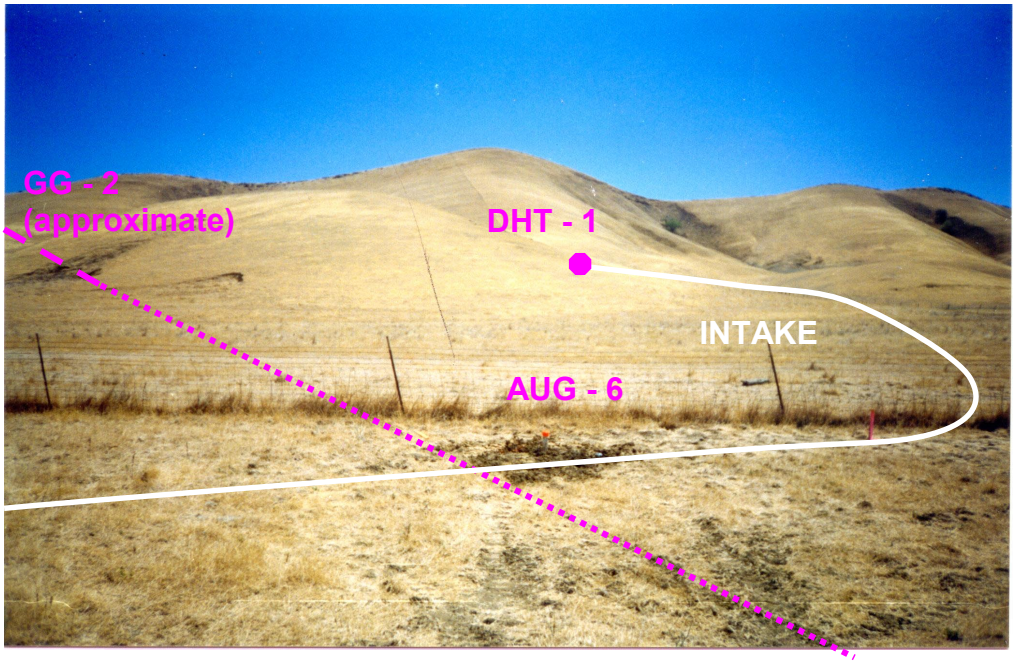


Photo 20. Eastern view of Golden Gate Intake Structure with AUG-6 and GG-2 fault

Seismic Refraction Surveys and Rippability

Six seismic refraction surveys totaling 600 feet in length were performed at the Golden Gate inlet-outlet works. Two of these were along the alignment for the intake works (SL-12 and SL-13), two were along the alignment for the outlet works (SL-10 and SL-11), one for the northernmost spillway option (SL-8), and one for the pumping plant (SL-9). Table 12 is a summary of the values calculated for depths to bedrock, estimated seismic velocities and rippability for the foundation at these locations.

Seismic lines SL-12 and SL-13 were surveyed on the far western edge of the shared intake. They indicated an alluvial thickness of about 10 to 10.5 feet, with seismic velocities ranging from 1,156 to 1,370 feet per second, averaging about 1,200 feet per second. These overburden materials can be excavated by common methods. The underlying mudstone and interlayered sandstone rocks of the Boxer Formation have seismic velocities ranging from 5,828 to 9,872 feet per second, averaging about 7,500 feet per second. These rocks may be rippable, especially where heavily weathered (Table 13).

Table 12. Golden Gate Inlet-Outlet Works-Seismic refraction data

First Horizon - Terrace Deposits							
Date	Line	Length (Feet)	Velocity 1 Forward (ft/sec)	Velocity 1 Reverse (ft/sec)	Composition	Rippability	Average Thickness (feet)
5/26/99	SL-7	80	1,300	1,300	Alluvium	Rippable	20
6/22/99	SL-8	100	1,600	1,500	Alluvium	Rippable	11
6/23/99	SL-10	100	800	800	Alluvium	Rippable	10
6/23/99	SL-11	100	1,200	1,200	Alluvium	Rippable	21
6/24/99	SL-12	100	1,300	1,200	Alluvium	Rippable	11
6/24/99	SL-13	100	1,200	1,400	Alluvium	Rippable	10

Second Horizon – Interbedded Sandstone and Shale						
Date	Line	Length (Feet)	Velocity 2 Forward (ft/sec)	Velocity 2 Reverse (ft/sec)	Composition	Rippability
5/26/99	SL-7	80	6,900	6,800	Sandstone/Shale	Rippable
6/22/99	SL-8	100	7,600	7,100	Sandstone/Shale	Rippable
6/23/99	SL-10	100	9,000	8,000	Sandstone/Shale	Marginal
6/23/99	SL-11	100	**	8,600	Sandstone/Shale	Marginal
6/24/99	SL-12	100	7,500	6,700	Sandstone/Shale	Rippable
6/24/99	SL-13	100	9,900	5,800	Sandstone/Shale	Marginal

* Seismic line 9 data was thrown out for inconclusive picks because of excessive seismic noise. The noise was most likely the result of active drilling of drill hole DHPP-1 within relative proximity when this line was being conducted.

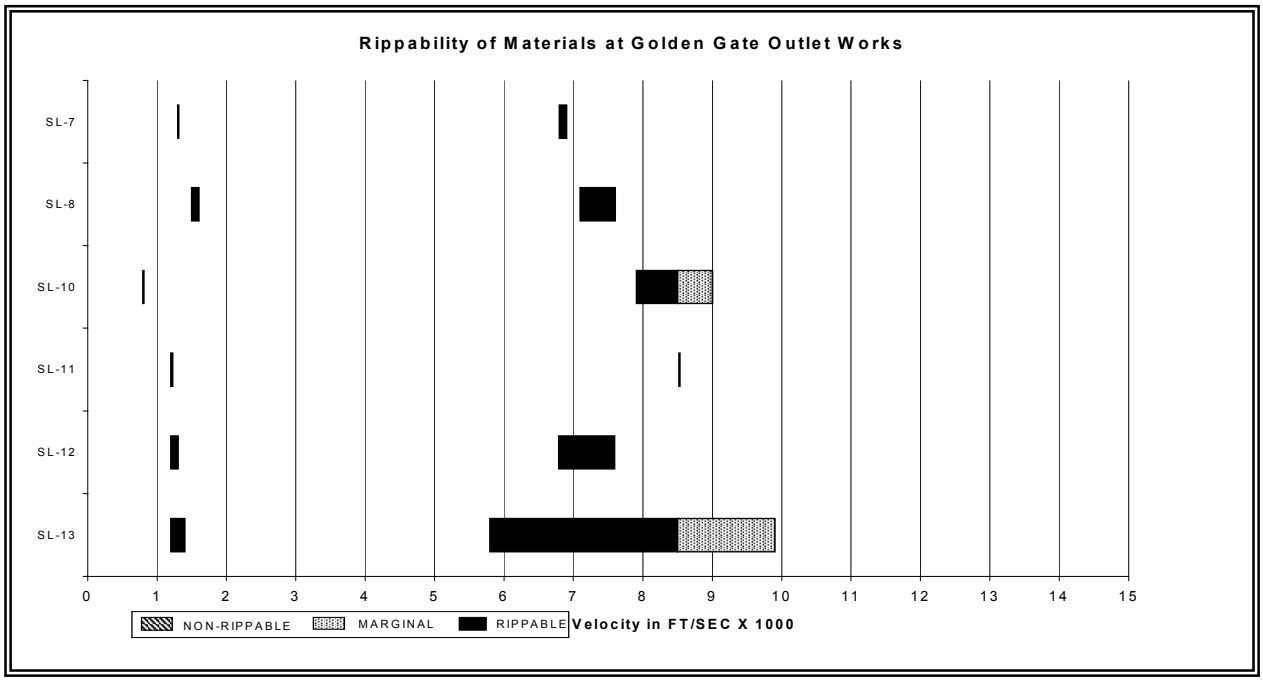
** Seismic line 11 has an excessively high forward velocity. This is probably due to bad picks; thus, this velocity was not used in any calculations

Rock strengths and grouting requirements of the foundation were not evaluated for the shared intake works because no core holes were drilled for this purpose.

Dewatering will be required during excavation of the intake works since groundwater is relatively shallow. A piezometer was placed in AUG-6 at the low western end of the intake in the drainage. It showed that water surfaces ranged between 7.3 and 8.5 feet in depth from August to December 1999.

Foundation preparation should include the removal of 20 feet of soil overburden and intensely weathered bedrock by common methods, with another 9 feet of moderately weathered bedrock that may have to be blasted and removed until firm foundation rock is reached. The underlying mudstone unit generally exhibits low permeability. Only minimal clearing will be required, as this is almost entirely open pastureland and grasses. A few small bushes exist in the drainage to Funks Creek.

Table 13. Golden Gate Inlet-Outlet Works-Rippability of proposed foundations



Tunnel, Penstock, and Gateworks

The proposed tunnel will be about 3,300 feet south of the right abutment of the Golden Gate Dam site. As at that site, the tunnel and gateworks will be excavated through sandstones and mudstones of the Cortina and Boxer Formations. Strike of the bedding is roughly north-south, nearly normal to the tunnel alignment, with a dip of 45 to 55 degrees to the east. A prominent joint set trends approximately east-west with near vertical dips. Based on preliminary drill hole data, tunneling conditions are not anticipated to be difficult. The east portal cut will be excavated in mostly sandstone with some mudstone interbeds. Some bedding plane failures may occur within the crown along laminar mudstone interbeds. Moderate overbreak may occur where shears and associated fractured rock are present. Support requirements are expected to be at most moderate for the tunnel with heavy support required only locally. Light to moderate weight steel supports on about 4-foot centers should be adequate for most of the tunnel length. The 30-foot diameter concrete-lined tunnel will extend about 4,000 feet with a maximum elevation at the western end of 350 feet and a minimum elevation at the eastern end of 270 feet. A 40-foot diameter, 350-feet deep gate shaft will be excavated about 1,200 feet upslope of the west portal at an elevation of about 550 feet.

Vertical drill hole DHT-1 was drilled to evaluate the rock conditions at the western tunnel portal (Photo 21). It was drilled to a total depth of 224.5 feet. No sample was taken in the upper 2.0 feet of overburden. From 2.0 to 224.5 feet the hole drilled through 60 percent mudstone with 40 percent sandstone interbeds. The permeability in the top 20.3 feet of the tested interval for DHT-1 is 0.24 feet per day and the Lugeon value is 8. From 19.4 to 219.3 feet permeabilities range from 0.00 to 0.26 feet per day, averaging 0.027 feet per day with Lugeon values ranging from 0 to 11, averaging 1.

Photo 21. CME-850 drill rig at western tunnel portal drill hole DHT-1 (note location of gate works still to be drilled)

Vertical drill hole DHT-4 was drilled to evaluate the suitability of the foundation rock at the eastern tunnel portal (Photo 22). It was drilled to a depth of 199.5 feet. It was drilled to 199.5 feet from July 6 to July 8, 1999. It drilled through 85 percent sandstone interbeds. Numerous shears were logged throughout the hole account for some of the high permeabilities and grouting requirements seen. Extremely pervious conditions are encountered from 17.1 to 70.0 feet, with an average permeability of 19.34 feet per day. A high grouting requirement (Lugeon value >100) is also necessary in this zone.

From 70.1 to 195.2 feet, Lugeon values are zero, indicating that grouting is not necessary. Permeabilities average 0.14 feet per day and range from 0.00 to 0.084 feet per day showing impervious to pervious conditions.

No seismic lines were surveyed at either of the tunnel portals.

RQD is often used as an indicator of the competence of rock. It is calculated by measuring all core recovered over 4 inches in length, then expressing that as a percentage of the total core recovered.

Photo 22. Eastern tunnel portal drill hole DHT-4

In general, calculation of RQD indicates that drill hole DHT-1 for the western tunnel portal drilled through rock of fair quality from 25 to 50 feet in depth, then excellent quality to 225 feet, except for a fair zone from 140 to 159 feet near the tunnel invert (Table 14).

Groundwater will be encountered during the excavation. Piezometers were placed in drill holes at either end of the tunnel alignment and in two auger holes along the shared outlet works. These showed that water surface elevations at the western tunnel portal have remained constant at about 30 feet in depth from August to December 1999. Water surface elevations at the eastern tunnel portal ranged from about 12.5 to 14 feet in depth from July to December 1999. The piezometer in AUG-3 bordering Funks Creek along the shared outlet works shows water levels ranged from 24 to 25 feet in depth from July to December 1999 (see Technical Memorandum C).

Water pressure testing was performed in each of the two tunnel portal drill holes. Water pressure tests in the western tunnel portal drill hole DHT-1 indicate that there will be low to no grout take to 225 feet, except for high grout takes from 9 to 20 feet, and 103 to 114 feet in weathered and/or fractured mudstone and sandstone. Water tests in the eastern tunnel portal drill hole DHT-4 indicate that there will be low to no grout take to 200 feet, except for high grout takes from 17 to 70 feet in weathered and/or fractured mudstone and sandstone.

Contact grouting and lining will be necessary for the full length of the tunnel. Grouting near the tunnel intake may be necessary depending on rock conditions.

The soil, colluvium, and intensely weathered rock at both tunnel portals can be stripped with common methods. It is estimated to be about 2 feet in depth at the western tunnel portal and less than 1 foot in depth at the east tunnel portal. Moderately weathered bedrock extends an additional 5 feet at both portals and should also be excavated.

Clearing will be minimal as the only vegetation is light grass.

Pumping Plant and Approach Channel

The proposed pumping plant is located with the western end of the approach channel about 2,000 feet southeast of the right abutment of the proposed downstream straight Golden Gate Dam site alignment. The channel extends about 4,300 feet east to Funks Reservoir. Sandstone and mudstone of the Cortina Formation would comprise the foundations. The strike of the bedding is generally north-south with a dip of 45 to 55 degrees to the east. Jointing trends mostly east-west with near vertical dips. The mudstone and interbedded sandstone is anticipated to be fresh and hard at foundation grade and should have adequate bearing capacity for the support of the structures. The colluvium and alluvium along the approach channel ranges from about 10 feet in depth on the east end to at least 35 feet at the west end. It is primarily silty clay with some gravel interlayers. The area of excavation for the pumping plant foundation is proposed to be roughly 1,800-feet long by 1,800-feet wide. Maximum depth of excavation will be up to 140 feet.

Vertical drill core hole DHPP-1 was drilled to help evaluate the suitability of the foundation for the proposed pumping plant (Photo 23). It was drilled to a total depth of 199.6 feet. No sample was taken of the top 5.3 feet of overburden. The rest of the hole consisted of 85 percent sandstone with 15 percent mudstone interbeds. Water testing of this hole showed high permeability in various zones, most likely due to fractured rock. The average Lugeon value from 38.3 feet to the top of the tested interval is 54; average permeability is 0.69 feet per day, indicating pervious conditions. Permeabilities throughout the remainder of the hole range from 0.0 feet per day to 2.48 feet per day, (average of 0.73 feet per day), with corresponding Lugeon values ranging from 0 to greater than 100, averaging 25.6.

Photo 23. CME-850 drill rig at pumping plant drill hole DHPP-1

Auger holes AUG-1 through AUG-3 were augered to evaluate the depth of soil and foundation suitability for the proposed approach channel (see Technical Memorandum A). AUG-1 was augered 11.0 feet to refusal on July 22. AUG-2 was augered 13.5 feet to refusal on July 1 (Photo 24). AUG-3 was augered 36.3 feet to refusal on June 26 (Photo 25). These all intersected terrace deposits bordering Funks Creek that consist of clay, silt, sand, and gravels.

In general, calculation of RQD indicates that the pumping plant foundation should have very poor rock quality to 36 feet in depth, then excellent quality to 200 feet (Table 14). The upper 20 feet of soil, colluvium, and weathered rock at the pumping plant foundation can be excavated with common methods. Below about 20 feet, the bedrock will require blasting down to invert grade. The upper 35 feet of terrace deposits, soil, alluvium, colluvium, and intensely weathered rock along the approach channel can be excavated with common methods. An additional 8 feet of bedrock may need to be blasted and removed to reach fresh rock.

Table 14. Rock quality designation in drill holes at Golden Gate Dam Inlet–Outlet Works

Agency	Drill Hole	Vertical Depth (feet)	Minimum RQD*	Maximum RQD*	Avg. RQD*	Description
DWR	DHPP-1	27 35	18	32	25	Very Poor
DWR	DHPP-1	36 200	84	100	98	Excellent
DWR	DHS-1	14 19	70	70	70	Fair
DWR	DHS-1	20 199	82	100	97	Excellent
DWR	DHS-4	32 55	0	70	38	Poor
DWR	DHS-4	56 200	60	100	96	Excellent
DWR	DHT-1	25 59	30	100	66	Fair
DWR	DHT-1	60 139	78	100	93	Excellent
DWR	DHT-1	140 159	28	100	67	Fair
DWR	DHT-1	160 225	94	100	99	Excellent
DWR	DHT-4	20 39	0	28	7	Very Poor
DWR	DHT-4	40 59	60	98	76	Good
DWR	DHT-4	60 74	100	100	100	Excellent
DWR	DHT-4	75 124	8	92	51	Poor
DWR	DHT-4	125 184	92	100	99	Excellent
DWR	DHT-4	185 200	48	90	69	Fair

*Rock quality designation (RQD) is developed by summing the total length as measured along the centerline of the drill core recovered in each run, but only those pieces of core which are at least 4 inches in length are counted that are "hard and sound." The sum is then represented as a percentage over the length of the run.

The first hole tested, DHPP-1, consists of sandstone and mudstone and has high permeability and grouting requirements in various zones throughout the hole, most likely due to fractured intervals. The average Lugeon value from 38.3 feet to the top of the tested interval is 54; average permeability is 0.69 feet per day, indicating pervious conditions. Permeabilities throughout the remainder of the hole range from 0.0 feet per day to 2.48 feet per day, (average of 0.73 feet per day), with corresponding Lugeon values ranging from 0 to greater than 100, averaging 25.6.

Photo 24. Site preparation at approach channel auger hole AUG-2

Groundwater will be encountered during the excavation. Piezometers were installed in the DHPP-1 drill hole and in the AUG-3 auger hole about 1,150 feet downstream to the east. The piezometer in DHPP-1 has shown water levels to be 15 feet below ground surface in summer 1999 and water levels to be 12 feet below the ground surface in winter 1999. The piezometer in AUG-3 bordering Funks Creek along the shared outlet works shows water levels range from 25 to 26.5 feet in depth from July to December 1999 (see Technical Memorandum C).

Clearing will be minimal at the pumping plant as the only vegetation is light grasses. Clearing at the approach channel will also be minimal except for some scattered pockets of riparian growth in the Funks Creek channel.

Spillways

The outlet works will also have a spillway designed to reduce the level of a full reservoir by 10 percent of its maximum depth in 10 days as mandated by DWR's Division of Safety of Dams. The location for spillway excavation depends on which Golden Gate Dam design configuration is selected. Two main locations are being considered. The northernmost spillway is linked to a curved dam axis configuration at the downstream ridge. The southernmost spillway location is linked to a straight dam axis at the upstream ridge. Each excavation would cross the two main sandstone ridges and have foundations consisting of Cortina sandstone with mudstone interbeds. Strike of the bedding is roughly north-south with a dip averaging 50 degrees to the east. A prominent joint set trends about east-west with near vertical dips.

Photo 25. CME-850 drill rig at approach channel auger hole AUG-3

Vertical drill hole DHS-1 was drilled to evaluate the suitability of the foundation rock for the northernmost of the two possible locations for the spillway (Photo 26). It was drilled to 199.0 feet at the base of the main sandstone ridge, at about the center of the proposed structure. It drilled through a reddish brown clay to 4.5 feet. From 4.5 to 130.9 feet, the hole drilled through 100 percent sandstone. From 130.9 to 163.0 feet, it drilled through 70 percent mudstone with 30 percent sandstone interbeds. It then went through 100 percent sandstone from 163.0 to 173.5 feet. From 173.5 to 194.8 feet, it drilled through 60 percent sandstone with 40 percent mudstone interbeds. From 194.8 feet to 199.0 feet, there is 100 percent sandstone. Water pressure tests in the northernmost spillway drill hole DHS-1 indicate that there will be low to no grout take to 200 feet, except for high grout takes from 17 to 70 feet in heavily weathered and fractured mudstone and sandstone. Average permeability from 16.0 to 58.9 feet is 1.01 feet per day, with an average Lugeon value 66. From 58.0 to 194.9 feet, Lugeon values and permeabilities both average zero.

DHS-1 is also a tight hole, consisting mainly of sandstone. Average permeability from 16.0 to 58.9 feet is 1.01 feet per day, with an average Lugeon value 66. From 58.0 to 194.9 feet, Lugeon values and permeabilities both average zero.

Vertical drill hole DHS-4 was drilled to evaluate the suitability of the foundation rock for the southernmost of the two possible locations for the spillway (Photo 27). It was drilled at the eastern base of the main sandstone ridge, at about the center of the proposed structure. It was drilled from July 10 through 12, 1999, for a total depth of 199.5 feet. The upper 0.0 to 2.2 feet of the section is composed of colluvial soil overburden and weathered sandstone and mudstone. From 2.2 to 167.5 feet, the section is composed of 80 percent mudstone and 20 percent sandstone interbeds. From 167.5 to 199.5 feet, the section is composed of 80 percent sandstone and 20 percent mudstone interbeds. Water pressure tests indicate that there will be low to no grout take to 225 feet except for high grout takes from 9 to 20 feet and from 103 to 114 feet in heavily fractured mudstone and

sandstone. Average Lugeon values for DHS-4 are 72 in the top 38.0 feet of the hole, indicating a high grouting requirement. Correspondingly, average permeability in the same interval is 4.5 feet per day. From 37.1 feet to the bottom of the hole at 195.0 feet, the formation is competent with an average Lugeon value of 0 and an average permeability of 0.02 feet per day.

Photo 26. Site of proposed northernmost spillway at Golden Gate Inlet-Outlet Works

Photo 27. Site of proposed southernmost spillway at Golden Gate Inlet-Outlet Works

Seismic refraction line SL-8 was surveyed along the northernmost spillway alignment at the eastern base of the main sandstone ridge. It indicated a colluvial thickness of about 11 feet, with seismic velocities ranging from 1,481 to 1,582 feet per second, averaging about 1,530 feet per second. These overburden materials should be easily rippable. The underlying mudstone and interlayered sandstone rocks of the Venado Formation have seismic velocities range from 7,128 to 7,570 feet per second but average about 7,350 feet per second. These rocks will not be rippable.

In general, calculation of RQD indicates that the northernmost spillway should have fair rock quality from 25 to 50 feet in depth, then excellent quality to 225 feet, except for a fair zone from 140 to 159 feet (Table 13). The southernmost spillway should have very poor rock quality to 40 feet in depth, then fair to excellent quality to 200 feet except for a poor zone from 75 to 124 feet.

Groundwater will be encountered during excavation. Piezometers were placed in both drill holes at each of the possible spillway locations. These show that water surface elevations at the northernmost spillway drill hole DHS-4 have decreased in depth from a maximum of about 200 feet in July 1999 to a minimum of about 27 feet in December 1999. Water surface elevations at the southernmost spillway drill hole DHS-1 have been artesian since the piezometer was placed.

On July 22, 1999, drilling exploration ended at the outlet works and the drill rig was moved north to the Sites northern saddle dam alignment.

Conclusions and Recommendations

The rocks that have been drilled should be adequate for the proposed foundations for each component. However, prior to construction we need to:

- Further evaluate the potential for seepage and/or wedge failure along the proposed tunnel alignment by drilling and water pressure testing. Dewatering may be an issue at the proposed southern spillway location.

- Drill three vertical diamond core holes along the top of the easternmost ridge, one to intercept the proposed tunnel at grade, and one for each of the possible spillway locations. (DH-3, DHS-2, DHS-3 on attached Plate 1)

- Drill a vertical drill hole at least 350 feet in depth down the center of the shaft for the proposed gateworks in the tunnel (DHT-2). This will probably require helicoptering a small skid rig to the drill site because the topography is so steep that grading a road for access will be prohibitive.

- Drill the right lateral tear faults that strike through the foundations for the pumping plant, approach channel, and southernmost spillway.

- Evaluate the possibility that the Salt Lake fault or associated deformation extends as far as the western base of the main sandstone ridge. This could mean that there are structural weaknesses in the proposed foundation for the intake works. This should be further evaluated prior to construction.

- Perform more seismic refraction surveys and auger holes as needed to better define overburden depths.

- Map all landslides that either exist on the footprints for the outlet works or that could impact the proposed facilities in any way.